Project Inshore

Stage 3 - Strategic Sustainability Review

A Guide to Stock Assessment and Setting Harvest Control Rules

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the authority on seafood

Shellfish
Association of Great Britain

CERTIFIED SUSTAINABLE SEAFOOD MSC
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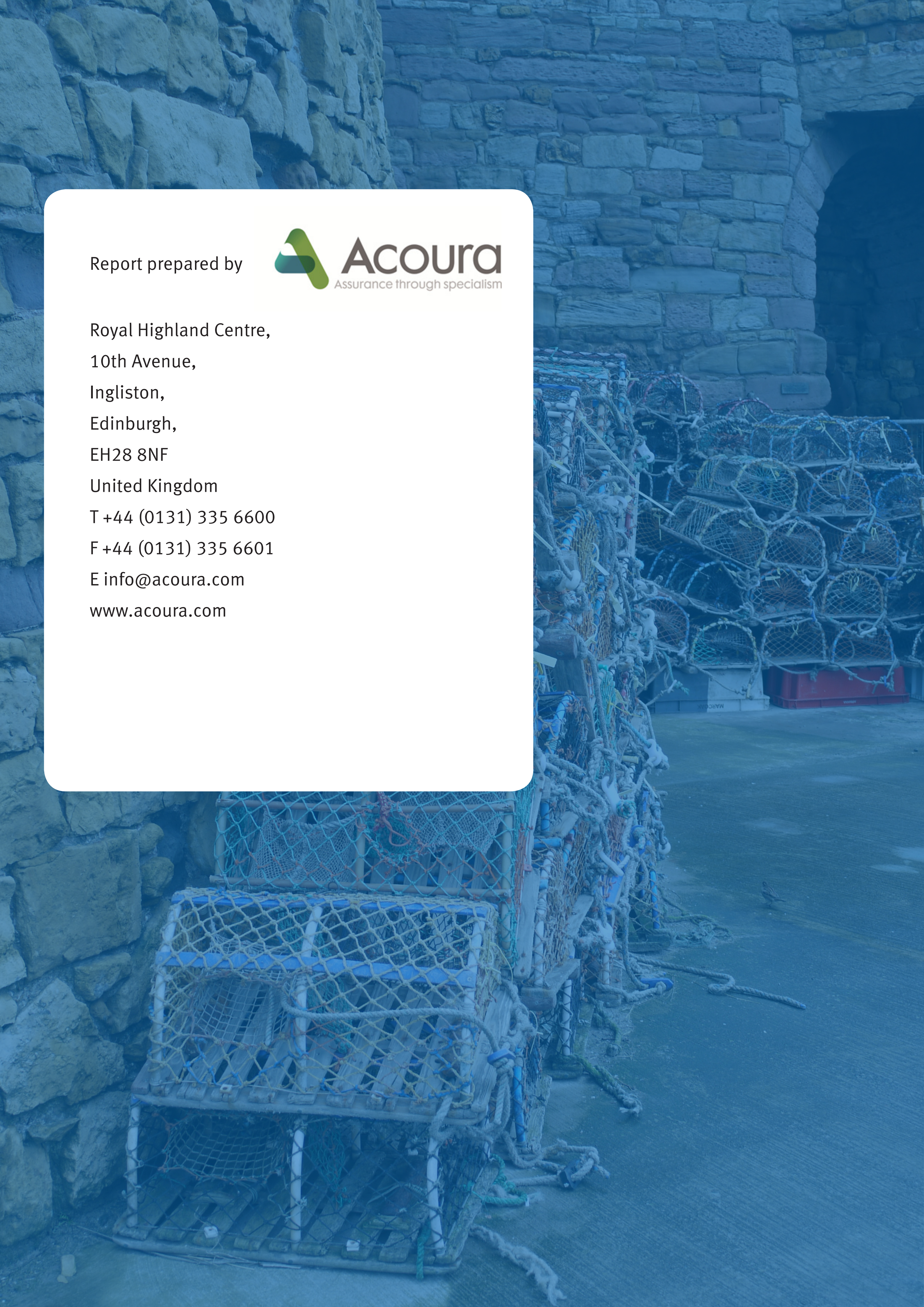

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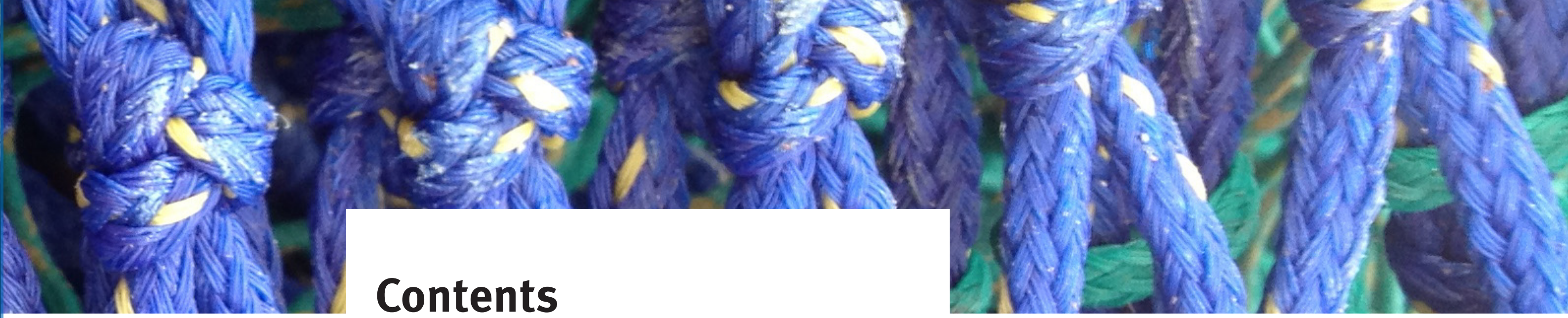

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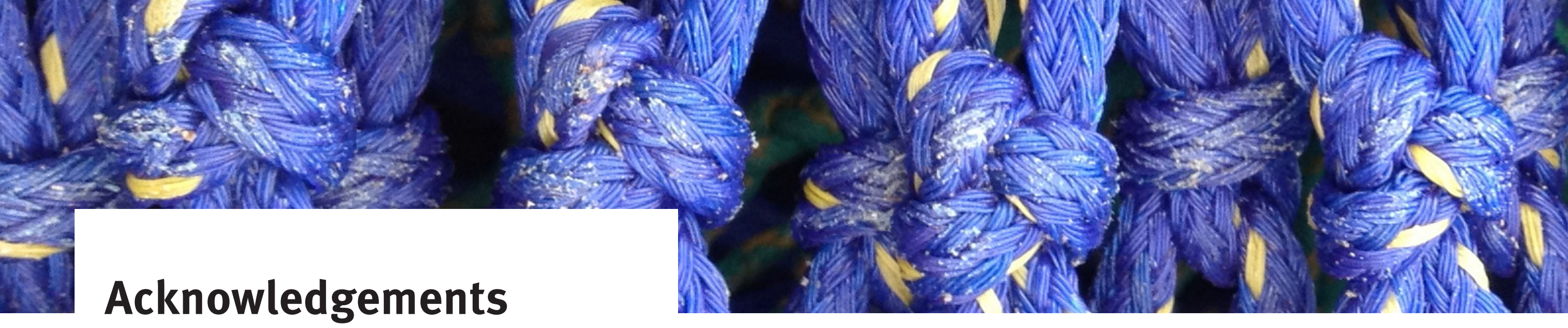

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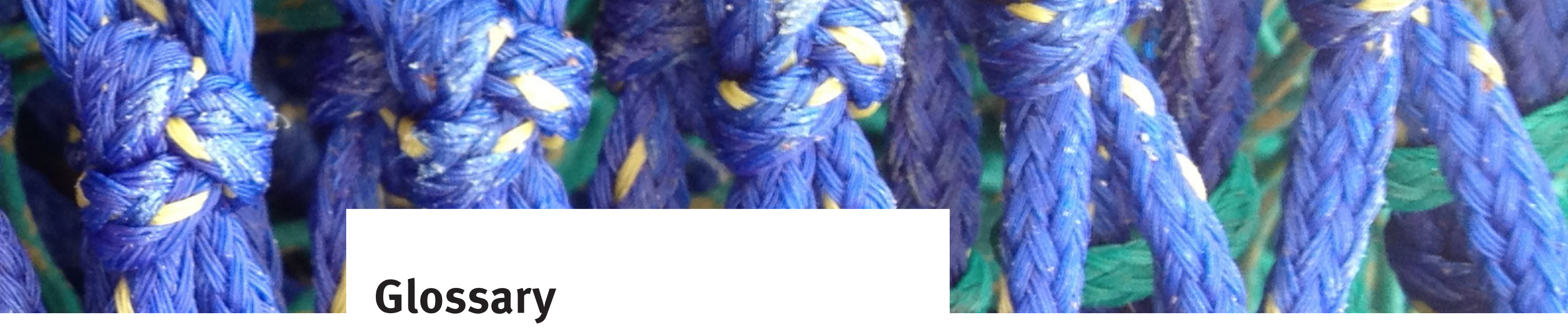


Glossary

ACOM	Advisory Committee (ICES)
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
CAB	Conformity Assessment Body
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CFCA	Community Fisheries Control Agency
CFP	Common Fisheries Policy
CITES	Convention on Trade in Endangered Species of Wild Flora and Fauna
COM	Common Organisation of the Markets
DEFRA	Department for Environment, Food and Rural Affairs
EC	European Commission
EEZ	Exclusive Economic Zone
EFF	European Fisheries Fund
EMS	European Marine Site
ETP	Endangered, Threatened and Protected Species
EU	European Union
FCI	Food Certification International
FIP	Fishery Improvement Plan
HCR	Harvest Control Rule
ICES	International Council for the Exploration of the Sea
IFCA	Inshore Fisheries and Conservation Authorities
IUCN	International Union for Conservation of Nature
IUU	Illegal, unreported and unregulated
JNCC	Joint Nature Conservation Committee
OSPAR	Oslo and Paris Conventions
MCAA	Marine and Coastal Access Act
MCS	Monitoring, Control & Surveillance
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
MoU	Memorandum of Understanding
MPA	Marine Protected Area
MSC	Marine Stewardship Council
NEAFC	North East Atlantic Fisheries Commission
NFFO	National Federation of Fishermen's Organisations
NGO	Non-governmental Organisation
NUTFA	New Under Ten's Fishermen's Association
Nm	Nautical mile
PI	Performance Indicator
PO	Producer Organisation
PSA	Productivity Susceptibility Analysis

RAC	Regional Advisory Council
RBF	Risk based Framework
SAC	Special Areas of Conservation
SAGB	Shellfish Association of Great Britain
SG	Scoring Guidepost
SI	Scoring Issue
SICA	Scale Intensity Consequence Analysis
SPA	Special Protection Areas
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
UoC	Unit of Certification
VMS	Vessel Monitoring System
WGNEW	Working Group on New MoU Species

Overview/Summary

One of the Marine Stewardship Council's (MSC) objectives in setting out its certification methodology is to give a practical definition of current best practice in fisheries management which fisheries can attain. This is useful not only for certifying fish products as from a sustainable source, but also as a useful guidance for fisheries to apply good management practice. However, the MSC standard still requires some interpretation for small scale fisheries, which remain under-represented among fisheries that have been certified.

It is central to the ideas behind certification that fishery stakeholders who believe that they apply best management practice and that their fishery is sustainable, can demonstrate this by becoming certified. It is up to those stakeholders to explain to an MSC assessment team the logic behind their claims of sustainability. Clearly therefore, it is necessary to provide evidence to support any such claim and test assumptions, as far as possible, so that an attempt to achieve MSC certification will be successful.

In this document we make a series of recommendations on how English inshore fisheries might meet the MSC standard without unrealistic demands on resources at the disposal of IFCAs. Both the MSC standard (e.g. MSC Certification Requirements v1.3 CB4.0.3) and FAO Code of Conduct (FAO 1995) indicate that the management system should be appropriate to the scale and intensity of the fishery. However, specific guidance has not given on what small scale fisheries might be expected to do where management and scientific research resources are severely limited.

This document will be most useful to those fisheries which cannot afford or do not have the capacity to conduct regular stock assessments, but are able to regularly collect basic catch, effort or size composition.

The basis for the recommendations made here is formed from three related ideas:

1. the use of simple statistics as monitoring indicators, and the construction of appropriate management decision-making using these,
2. localised management of fisheries by their stakeholders, but with some external oversight, and
3. the application of the precautionary approach where there is uncertainty.

The proposed management system needs to be commensurate with the scale of the fishery. All the recommendations here take this into account. It is not necessary to conduct an extensive scientific programme to understand the population dynamics of the exploited stocks in order to achieve sustainable management. This can be achieved with pragmatic management controls applied through an adaptive system. On-going research allows the fishery to improve exploitation and reduce precaution that was necessary in the absence of relevant information.

The process of developing and justifying a harvest strategy is proposed as follows:

1. Management unit: Define an appropriate stock management unit, based on the known biology, extent of the fishery and the precautionary approach.
2. Stakeholder participation: Recruit stakeholders to develop and support the management initiatives. An important benefit from MSC certification has been the increased co-operation between stakeholders in trying to achieve the MSC requirements. In particular, successful MSC certification has been accompanied by greater co-operation of the fishing industry. This can greatly help reduce management costs as well as make enforcement and data collection effective.
3. Data Collection and Indicators: Review data which might be collected on the performance of the fishery. This should include at least one source of information on the abundance of the target stock. In some cases, it would be useful to separate initial intensive data collection from less intensive long term monitoring to help develop an appropriate harvest control rule. Simpler empirical indicators are recommended, not only because they easier to understand by

stakeholders, but they are also simple to estimate and test.

4. Harvest Control Rule: Agree a well-defined harvest control rule based on the indices and limits on fishing that might be applied. Evidence will be required that any harvest control rule is consistent with the available knowledge about the fishery and should achieve fishery objectives.
5. Review and Evaluation: Seek to have an independent review of the process to ensure management objectives should be met. This could also lead to a research plan to address those areas of greatest uncertainty.
6. Fishery Management Plan: Compile all relevant information into a single document.

We focus on implementing harvest control rules based on simple empirical indicators of stock status. Harvest control rules encapsulate good management of the target stock, as they define practical objectives, measures of performance and appropriate management actions required to ensure fisheries meet their objectives. Good harvest control rules should have the following attributes:

- Testable: It should be possible to test harvest control rules with the best available science and covering possible states of nature (uncertainties), providing evidence that the management system should work.
- Transparent: The harvest control rule should clearly define objectives and how management will respond to changes in the fishery, accessible to all stakeholders.
- Auditable: Explicit reporting of indicators and decisions against those agreed in the harvest control rule allows stakeholders to see whether management is following its own agreed policies.
- Participatory: Identifying and agreeing the harvest control rule is the task of all stakeholders. Scientists can help the process by providing information on “what if” scenarios through simulating using the decision rules.
- Timely: Harvest control rules consist of pre-agreed actions to be taken in response to changes in stock status. This may be particularly important where stocks status may change rapidly (e.g. bivalve and shrimp stocks).

It is important to note that the recommendations made here are the views of the project team, and would not necessarily be shared by conformity assessment body experts assigned to a particular assessment. It would be up to the fishery applying for certification for making its case as to why the fishery is sustainably managed, and that may or may not use some of the ideas presented here.

There is considerable overlap between the MSC standard, the ICES fishery advisory guidelines, the Marine Strategy Framework Directive (MSFD) and conservation objectives in European Marine Sites (EMS). A single well designed harvest strategy should also deliver obligations under these directives and standards.

Explanation of MSC Principle 1

The generic structure for the MSC Principle 1 performance indicators (PIs) focuses on two key components of a fishery‘s performance

1. Outcomes or the current status of the target stock
2. Harvest Strategy (Management) which includes a number of MSC scoring performance indicators (PIs):
   - Reference points
   - Harvest strategy
   - Harvest control rules and tools

- Information and monitoring
- Stock assessment

Harvest Strategy (Management) related PIs are strongly interrelated and collectively indicate whether there is a clear, scientifically based, agreed and planned approach to managing exploitation of the target species. An integrated (in the sense that all the PIs act together) harvest strategy is, in reality, simple in concept (Fig. 1).

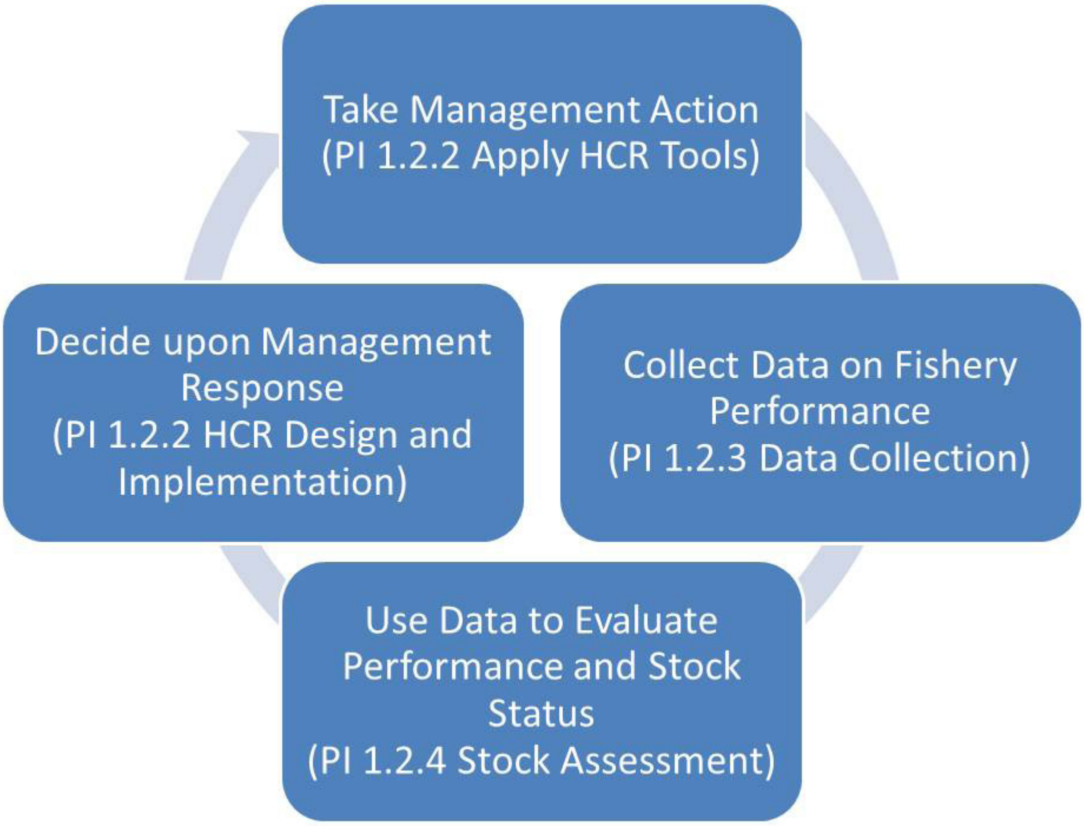
The integrated harvest strategy as described in the MSC standard reflects fishery management "best practice" and provides a strong framework for sustainable fisheries irrespective of any ambition to achieve certification.

There are certain Principle 1 scoring issues in the MSC certification which are not emphasized in this report. In certifying a fishery under the methodology in CR1.3, these scoring issues would need to be addressed. However, the MSC methodology is likely to change, and we believe that there will be increased emphasis on the harvest control rule. A harvest control rule (PI 1.2.2) incorporates issues related to data collection (PI 1.2.3), assessment of stock status (PI 1.2.4), reference points (PI 1.1.2) and rebuilding (PI 1.1.3). Therefore, developing a well-founded harvest control rule should address the range of issues related to Principle 1.

Figure 1:

Simple management process cycle, which occurs in all fisheries

The MSC framework seeks to ensure that this cycle is properly applied so that it is reliable, transparent, timely and is highly likely to achieve stated management objectives.



Information and monitoring, coupled with stock assessment, is used to indicate stock status (**PI 1.1.1**). This is an estimate or an indicator of the true stock – the true stock is never known exactly. Reference points (**PI 1.1.2**) indicate the desired (target) or lowest tolerable (limit) position for the stock. These may be known from the relationship between biomass and productivity (in relation to the target) and biomass and recruitment or may be based on previous experience with the stock, or may simply be based on expert judgement.

The basis for the reference points will really depend on how the stock status is measured. In the MSC scheme, and as generally applied, the target point is equivalent to the point at which the productivity and yields from the stock are expected to be at a maximum over the long term. The

limit point represents the point where there is a risk of recruitment depression or failure. That is, as the stock approaches the limit point the risk of recruitment failure increases to unacceptable levels and as the status moves towards the target the risk reduces and the productivity of the stock increases.

Under a particular fishery regime the stock status will change over time. In a new fishery for instance the initial biomass (B_0) will decline as the stock is fished down (Box 1). With an active and well understood harvest strategy, a pre-agreed harvest control rule (HCR) will be applied so that as the stock status approaches the limit reference point, the decline will be reversed before recruitment failure occurs. The requirement to act in this way is mandated by MSC PI 1.2.2. The point at which such a decision is invoked is not specified but it is good practice and risk averse to avoid coming close to the point where recruitment could fail. A threshold for such a decision, lying between the target and limit reference point, should be used by management.

If the stock is below the limit reference point or is simply regarded as 'recruitment impaired' or moving towards that point then the fishery will not be eligible for certification. If the stock is consistently below the target reference point, then a re-building plan will be necessary.

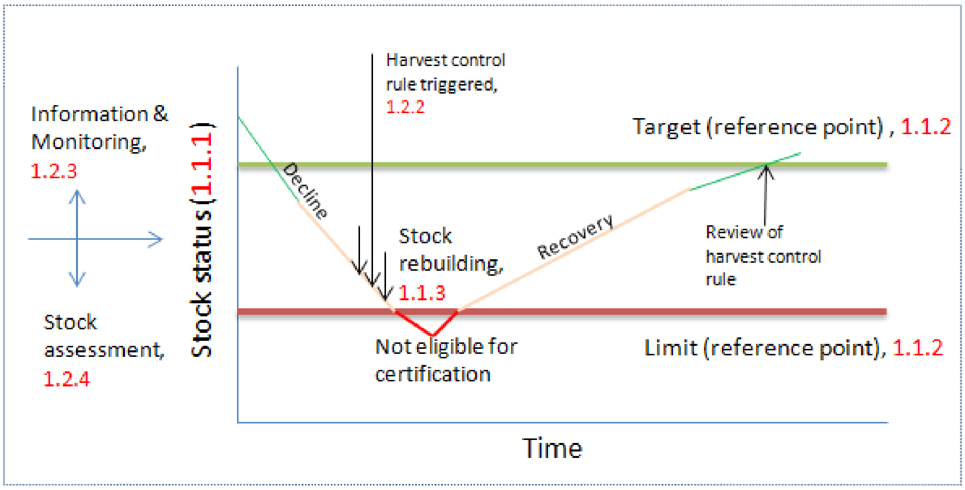
Re-building will need to be within a specified time frame. Therefore evidence that rebuilding should occur within a reasonable time frame (within 2 generation times or 5 years) is useful to justify a harvest control rule.

Obviously the capacity to show changes in stock status, with reasonable precision, is extremely important within any harvest strategy. If the assessment of status is imprecise or inaccurate then decline or recovery may not be detected, false decline or recovery may be detected and HCRs may be applied incorrectly. Therefore, the decision as to how to measure stock status and the data to support this measurement is vitally important.

Box 1:

Example scenario for a harvest strategy employing a harvest control rule to rebuild a stock.

Harvest strategy, 1.2.1



The figure illustrates a scenario where, with a decline in stock status, management responds by decreasing the harvest, so that the stock is rebuilt. In this scenario, the stock falls below the limit reference point, at which point the recruitment will be put at unacceptable risk. The MSC requires a harvest control rule that will act so that there is a very low probability that this will occur. While the stock is below the limit reference point, the fishery cannot be certified and would be suspended.

In reality, the road to recovery might be protracted, unclear and with periodic reversals because of variable recruitment, ineffectiveness of the control rules etc. This will test the endurance of stakeholders involved in implementing the harvest strategy. Much of the discussion at this point may centre around different perceptions of stock status and the effectiveness of the HCR and the tools used to implement it. This is a critical point for managers; inaccurate or imprecise measures of stock status have the potential to cause chaos in the management process.

Management Unit

Stock and fishery boundaries should be decided at the outset in order to design the harvest strategy. Defining the management unit to coincide with a true isolated fish population is probably impossible. Some level of pragmatism is required in determining management unit boundaries (Begg et al. 1999). However, it is necessary that management is able to control the exploitation rate and stock abundance by altering the level of harvest. As long as this can be achieved, a harvest strategy should be able to achieve objectives related to sustainability, and therefore arguably meet the MSC standard even if it is suspected there is some migration between populations outside the direct control of the management authority.

Although there are implications of not choosing the correct stock boundaries, knowledge of the known distribution of fishing, likely dispersal distances of larvae and known behaviour of juveniles and adults can be used to make pragmatic, expert judgement based decisions.

Assuming the local population can be treated as a management unit is the most precautionary option. Applying appropriate management controls should not wait while research is being conducted. Even if the stock is shown to be shared, beyond increased co-operation, good practices are unlikely to change much locally. Therefore, it is most precautionary to assume that local populations, in the absence of information, are self-contained and can be locally managed unless it can be proved to the contrary.

For many shellfish, the adult population boundaries may be easy to define since the adults are often sedentary and will not move much. In some cases (bivalves species), adults will effectively not move at all. Therefore, the local abundance of adults might be controlled quite effectively. For these stocks, it is the pelagic larval distribution and therefore how the spawning stock abundance should be measured and protected, that might be most contentious.

The management unit is not only dependent on movement of fish, but also fishers. Unit boundaries will often be determined by political or authority boundaries. In this case IFCA and territorial water boundaries are most relevant. Significant fishing outside the authorities control undermines the harvest strategy and may well render it ineffective. It is important that the authority has control over the overall level of exploitation, if possible. Lack of overall control on harvest levels will prevent the fishery meeting the MSC standard.

Many English inshore fisheries, at least in theory, do not apply limited entry. This suggests that the IFCAs could have difficulty in controlling access to many resources within their control, so it may be difficult to argue that local resources are a single unit without reference to other IFCAs, fleets or even international authorities (EU). This severely complicates management, undermines any local initiative and would probably prevent certification in any but the long term.

The argument for a particular unit of management needs to be clearly made in the harvest strategy and documented in the fishery management plan. If there are doubts as to whether local management can be effective, it will be necessary explicitly to consider whether the harvest strategy is able to achieve its aims as part of the evaluation.

Stakeholder Participation

For small scale fisheries, it is almost a prerequisite that stakeholders are involved in developing and implementing the management system. Alternative approaches are costly and much less likely to be successful. MSC certification is a way to encourage participation and reward the fishing industry in applying good management practice. Greater participation lowers the cost of management and greatly increases the probability of success, particularly in diverse small-scale fisheries. A lack of stakeholder co-operation in small scale fisheries would essentially prevent any chance for MSC certification.

Stakeholders have two main tasks. Firstly, they must develop and monitor the management system, including the development and implementation of the harvest control rule. Secondly, they usually must co-operate with, or actually implement, the data collection programme.

Overseeing the harvest strategy is probably best done by setting up a committee or working group for each fishery made up of stakeholder representatives. Seeing that the main task of such a group will be to implement good management practice, the MSC standard can be used to define their terms of reference. Requirements would include justifying decisions, publishing minutes of meetings and allowing public attendance. The committee may not only oversee implementation of the harvest control rule, and review and evaluate the performance of the harvest strategy and its components, but also be the target for reports on any research findings and scientific advice.

An important task of the stakeholder group would be to ensure good monitoring data are being collected for decision-making. Providing data can most easily be achieved with the co-operation of fishers. Not least, stakeholders are more likely to believe their own data when it comes to accepting short term management actions which may be costly to the industry. Using fishers to provide data decreases collection costs for management, increases the amount of data available and improves coverage compared to other approaches. For many small scale fisheries, this is the only realistic approach.

It is important to recognise that data collection incurs costs for fishers, so any method used should be as easy and as fast as possible. Therefore, fishers should be directly involved in designing the data collection programme. If data are to be provided by fishers, it is strongly recommended that reporting can be made electronic. This decreases the errors and greatly decreases the costs in data collection and management. Opportunities for data collection through cheap hand-held devices (e.g. smart phones with simple applications) and internet applications (freeware such as MySQL, PostgreSQL, PHP etc.) have never been greater.

Encouraging fishers to engage in data collection programmes in a sustained and systematic is more likely to succeed if:

- The purpose of the data collection is made clear. And explicit management plan which describes the harvest strategy and reference points and the 'IF THEN' actions to be taken will make the purpose clear.
- Data are reported back to the fishermen who generate it at individual vessel level and at fleet level. Individual vessel reports provide an 'accounting' service to vessels operators regarding catch and effort and its variability which can usefully be translated into gross and net profits.
- The fishery has restricted access or limited entry as this greatly enhances the sense of ownership and that benefits will accrue to the group who are providing the data.

Data Collection

Types of Data

FAO (1998) provides extensive information on good practice in developing data collection systems that can be used to measure performance in relation to management policy and objectives. Indicators can cover a wide range of social, economic and biological performance measures. For the purposes of this report, we are only going to consider measures related to stock and exploitation status.

Every fishery is different, and management is likely to want to develop a variety of indicators which can be used to guide management decision-making. Table 8 outlines the simple indicators which are likely to be of use for small scale fisheries. These are based on fishery dependent data which should be routinely available. Table 2 provides an outline of the data which might be recorded for each stock and gear type.

Even if the capacity to undertake stock assessments internally is limited, data in a suitable form and quality will significantly reduce the costs of outsourced stock assessments when they become desirable.

Routine data collection forms the fundamental information gathering for the management authority. It is a core responsibility because good management cannot be implemented without some sort of monitoring. Ecosystems are too complex and unpredictable to be managed without

constant feedback to adjust controls.

Total catch weight will be generally required for all fisheries. It should be possible to obtain total catch weight from each stock with current levels of data collection. It should also be possible also to obtain catch values from the same sources for economic monitoring. At least some of the catch data should be linked to a measure of fishing effort – how much work was required to obtain the catch.

Following good information on catch and effort the second 'tier' of data that is usually feasible to collect is size composition data. However, before embarking on this more expensive form of data collection it should be clear what indicators or assessments are to be derived from them and how it will advise the harvest strategy.

Size related monitoring will require two types of measures:

- Fishers can report, for many species, the number of fish they land as well as the total weight. This can be used to estimate the mean weight of the fish being landed.
- A sampling programme can be conducted where fish are measured by data collectors. This would require employing staff to carry out measurements in sufficient numbers so that there is enough data to represent landings size composition. Given the cost of such an exercise, it should probably be reserved for only the more important stocks, if any. Alternatively, fishers could report simple size measures (such as weights or length measures) for at least some of their landings.

For a number of species, notably the crustaceans (lobster, crab) and molluscs (cuttlefish), data collection staff or fishers should also be able to report the sex composition of the catch. Depending on the life history characteristics of the stock, reporting catches by sex or sampling to obtain the sex ratio may provide further useful information.

Measures of fishing effort are more complicated to estimate than catch due to differences in fishing gear and the way they are used. Measures of effort are used as proxies for fishing mortality and for costs of fishing. Different measures may be useful for each type of use, but here the discussion will be limited to measuring effort for fishing mortality and CPUE as a measure of abundance.

Effort needs to relate to the proportion of the stock which might be caught by the gear. This usually involves measures of swept area for active gears such as trawl, or the soak time multiplied by the volume of gear for static gears (Table 9).

Effort is often standardised. This uses different covariates to try to generate a common measure of effort and CPUE between different gears and fishery operations. Specifically, covariates need to be recorded which account for different fishing efficiencies. However, recording gear specifications will be necessary to monitor potential changes in gear efficiency over time, which can otherwise render fishing effort useless as an indicator.

Fishers will need to review the data collection programme for the practicality of providing the required data as well as the value in providing the relevant information. Particularly in respect of gear specifications, it is important that the fishers who use each gear indicate the parameters which are important and which should be recorded.

Sampling error will be an important consideration in choosing any indicator. Error can be minimised by maximising the number of fishers who provide data, applying a rigorous sampling methodology where necessary and using simulations to develop data treatment which can reduce error to acceptable levels. It is possible however that some indicators may have to be rejected because they do not provide accurate enough monitoring at a low enough cost.

Efficient data handling will form a necessary part of the monitoring system. Paper based methods are expensive, liable to error and often do not report back to those providing the data. As the system would be based on voluntary data submission, the most simple and cost effective method would be to require fishers enter data directly on to the computer themselves.

Computer applications would not only store data for monitoring purposes, but also report to users information relevant to their fishing activities and business as required, making such a system of greater direct use. It should be noted that processors already have databases, which can be extended to report any data required to manage the fishery while maintaining commercial confidentiality.

Any system would need to respect data confidentiality as required by the users. It is likely that users would be comfortable with aggregated data been reported publicly, but not the individual detail records. Confidential data could be made inaccessible and only available for an individual's applications. It would be important that any of these data not be available for enforcement purposes.

Data Quality

As the harvest strategy will rely on time series of data on stock status data continuity is vital. The responsible authority must be committed to an agreed data collection programme in the long term. A scientist can provide the technical specifications for any work, but the decision and commitment to implement and 'stay the course' with the programme is a corporate decision.

It is important to ensure good quality data, even if this limits the range of data being collected. For many fishery, a wide range of data are often available, but few are comprehensive, complete and of high quality: landings may be under reported, effort information in logbooks may be ambiguous, and so on. A lot can be done with a good quality time series of catch and effort, but almost nothing can be done with such data if there are question marks over it.

Standard Operating Protocols (SOPs) for data collection and deriving the indicator are useful to avoid inconsistencies in time series and particularly where personnel dealing with data may change over time

Any reliance on outside bodies should be carefully assessed and MOUs or contracts developed with such bodies. The same requirement may apply to co-operative work between the management authority and the fishermen or may apply across IFCA boundaries etc depending on the stock structure.

Data management is very important; data loss, loss of corollary information as to what data means, 'knowledge' resting with too few people, clumsy data storage and subsequent time consuming data compilation and analysis are important issues for long term data collection programmes. Careful documentation and good backup procedures go a long way to addressing these problems.

The fishery management must also ensure that its actions do not decrease the information content of monitoring indicators, but should try to enhance the value of indicators wherever possible. Changes to various management controls can violate assumptions that are need to interpret indicators (Table 8). For example, changes to minimum size or technical changes to gear may alter both catchability and selectivity. Such changes can be handled statistically, as long as adjustments are made to the data collection and the way the new management control is implemented.

Table 1:

Variables likely to be used as the main indicators for the stock or exploitation status

Variable Name	Proxy for...	Possible Reference Points	Main Assumptions	Recorded Data
Effort	Fishing mortality	Target: 120% Effort at MSY Trigger: Effort at MSY Limit: 60% Effort at MSY	Relationship between fishing mortality and effort Catchability constant	Total effort each trip
CPUE	Biomass	Target: 120% CPUE at MSY Trigger: CPUE at MSY Limit: 60% CPUE at MSY	Relationship between biomass and CPUE Catchability constant CPUE when stock unexploited	Total catch each trip Total effort each trip
Mean Length or Weight	Fishing mortality (Yield-per-recruit)	Target: $F_{0.1}$ Trigger: $SPR_{40\%}$ Limit: $SPR_{20\%}$	Constant selectivity Growth parameters Length weight parameters Natural mortality Size at 50% maturity	Catch and size composition of landings Total numbers and total weight of fish each trip

Table 2:

The data collection by stock which could be carried out for the calculation of indicators

Not all indicators will be calculated for all stocks, but will depend upon what data might be obtained. Final choice of data collection programme and indicator will be decided upon by the management authority when initiating the process.

Species	Gear	Data Collected	Possible Indicators	Issues
Seabream Seabass Red mullet Sole Mackerel	Angling	Number of rods Time fishing Total catch weight Number of fish Sampled length	Mean length Mean weight CPUE	Stocks shared outside region Stock assessment already covered by ICES assessments
	Set Net	Number of nets Net length Hours fishing Total catch weight Number of fish	Mean weight CPUE Effort	
	Trawl	Trawl net width, speed and time of trawl (swept area) Total catch weight Number of fish		
Lobster Crab Cuttlefish Whelk	Traps	Number of traps by type Hours soak time Total catch weight Number of fish	CPUE (catch per trap soak time) Mean weight Mean carapace/shell length by sex Sex ratio Weight and sex composition Length and sex composition	Stocks adult and/or recruitment shared outside region Trap CPUE usually poor, so may need research
Scallop Oyster	Dredge	Number of dredges Dredge width, speed and time of dredge (swept area) Total catch weight Number of oyster	CPUE (catch per dredge swept area) Mean weight Mean shell width Weight composition Length composition Age composition	Stocks recruitment shared outside region

Empirical Stock Status Indicators

Overview

Although indicators may be required to evaluate other aspects of fishery performance, we only consider stock status here.

It is important to evaluate whether the quality of any proposed indicator is good enough for its intended purpose (Table 10). It is easy to embark on a data collection programme only to find that the resulting indicator is not acceptable for decision-making. The ensuing ambiguity and 'arguments' among stakeholders can be costly and time consuming.

The possible indicators will be limited by the availability of data which can be realistically collected on a routine basis. Appropriate indicators will need to be calculated with the best

available data that can be collected from each species / gear. It is possible that a trial period of collection will be required for each fishery to obtain a sample of data.

The properties of an indicator will need to be investigated in each case. The behaviour of the indicator and its interpretation can be tested through simulation after some data have been collected. The indicator will need to be robust in that it should not be too sensitive to assumptions which may not strictly hold.

It is likely that where data are taken from a small number of fishers, the resulting indicator could be very noisy. This can be reduced in a time series index by using statistical smoothing techniques.

The interpretation of any indicator will also depend upon various assumptions, some of which may be critical to the decision-making. For example, increases in fishing gear efficiency will invalidate a CPUE abundance index if proper account is not taken of the changes. These assumptions will need to be considered in developing an indicator and will need to be monitored to make sure that the assumptions are met.

While many indicators of stock performance may be considered, a well-defined harvest control rule will need, most likely, to be bound to one quantitative measure of stock productivity, usually stock abundance. For small scale fisheries, we recommend using a CPUE indicator, since it is simple, easy to understand and has a useful meaning to most stakeholders. It may also be useful to consider using mean size, but interpretation of average length may be more hindered by assumptions and more difficult to interpret. Other indicators (e.g. spawning stock biomass, fishing mortality, size ratios, total biomass) may be desirable, but, within the context of a harvest control rule, will become increasingly difficult to estimate, understand and test, making them less appropriate for small scale fisheries.

Catch per Unit Effort

The basic data for fisheries are inputs (fishing effort) and outputs (landings). These are the cheapest data to collect, as long as fishers provide good data. Various catch rate indicators can be derived and reported as nominal (observed) values or standardised to remove effects of other variables.

CPUE is particularly useful for the following reasons:

- CPUE is often assumed, with good reason, to be approximately proportional to abundance.
- CPUE or catch rates may indicate the economic performance of the fishery as a whole. Thiscould allow a harvest control rule to focus on economic performance, while also ensuring the fishery meets its conservation objectives.
- CPUE is well understood by fishers and other stakeholders, making harvest control rules based on this indicator also easier to understand.
- The CPUE indicator is very flexible. Both catches and effort may be measured in different ways, helping to remove bias and fine tune the indicator so that it serves it purpose better. For example, catches may be split into landings and discards. Where discarding is related to size, such as in lobster and crab, discards per unit effort may provide a useful recruitment index.

Additional variables may be useful in standardising effort and CPUE include vessel and gear attributes, location and time of fishing. These will vary from fishery to fishery and most fishers will be aware of appropriate attributes. While CPUE can be standardised using, for example, generalized linear models, this adds considerably to the complexity the calculation of the indicator and make it difficult to understand. Such complexity should only be added where it is strictly necessary.

CPUE may be unsuitable for three reasons:

1. Hyperstability: CPUE may not respond to changes in abundance, because density in the fished area remains relatively constant, fishers adjust their activities to compensate for declining

CPUE or there are changes in catching efficiency (e.g. pot saturation).

2. Changing catchability: Gear and vessels tend to improve over time, which would maskdeclines in CPUE due to declines in abundance.
3. Changing productivity: Stocks may change in productivity over time, due to environmental and other effects. Changing stock productivity would not invalidate the indicator, but its interpretation would need to be adjusted.

Data collection should aim to collect co-variates which can detect and correct for these effects if they are thought to be likely.

Mean Size Indicators

An alternative simple indicator to CPUE would be mean size (usually length), which can be used as an indicator of fishing mortality. Simply put, the smaller the animal relative to its maximum size, the higher the exploitation rate. The Beverton–Holt length-based mortality estimator (Gedamke and Hoenig, 2006) could be used to interpret a time series of mean lengths (or weights with a length-weight relationship). With spawner-per-recruit, it should be possible to define reasonable precautionary reference points and use these results to define a harvest control rule. However, to our knowledge, this has not yet been done.

Other Indicators

Other empirical indicators of stock status could be developed, but are unlikely to be as useful as either mean size or catch rates. They might be useful where catch rates are difficult to estimate, and would most likely be variants on mean size indicator above (e.g. ratios between mature and immature fish in the catch). As these would not have been used before, their performance would need to be evaluated in more detail.

"Parametric" indicators, such as fishing mortality (F) and spawning stock biomass (SSB) estimated from parametric modelling of the available data, are beyond the scope of this report. In many cases, however, parametric indicators will be the best choice where there are monitoring data are collected from a variety of sources (e.g. catch and survey size composition and different abundance indices). Stock assessment models are able to combine information from a variety of data and eve deal with apparently conflicting signals among data sources. For these type of indicators, the management authority will need to have high resources and technical capacity.

Size composition of landings or catches (including discards) can be used in various stock assessment analyses to estimate spawning stock size and fishing mortality. For some species of mollusc, ageing is also easy to carry out, and these data can greatly enhance such analyses. Other data collected for shellfish includes fishery independent surveys. These provide absolute estimates of biomass, which can be used directly in setting harvest levels. Where these are not paid for by the industry, they can be considered a subsidy. While such subsidies do not encourage overfishing, they also do not encourage industry to work on reducing management costs. For these fisheries, moving to empirical indicators based on catch and effort may significantly reduce management costs.

Indicators produced from stock assessments combine information from different sources (catches, abundance indices, size and age compositions) into a single best estimate of status. This represents the standard approach which has been advised for most fisheries and considerable information already exists on stock assessment based management (e.g. this is the ICES approach). For intensely fished resources, this is the preferred approach.

In estimating indicators, dynamic models are much preferred to those assuming equilibrium. However, repeated application of simple equilibrium models such as catch curves or Beverton-Holt mean length estimators (Gedamke and Hoenig 2006) should track fishery performance, and may be a useful tool to smooth out errors without resorting to a full complex dynamic model. However, dynamic age structured models not only allow all data to be used, but also can allow quite rigorous tests of assumptions and consistency in data interpretation, and therefore remain preferable.

Table 3:

Evaluating the properties of indicators prior to embarking on a data collection programme

Adapted from Rice and Rochet (2005)

Property	Attributes	Description	Example
Concreteness	- Physical or abstract - Units measurable - Observed or model output	Does the indicator have defined units of measurement and is it observed from empirical data or derived from a model	Effort can be defined and measured in units. It is observed (nominal) but can also be modelled to remove the effects of confounding variables (season, spatial, vessel effects)
Theoretical basis	- Not contested - Credible but debated - Credible with competing theories - Untested	The indicator should ideally have a sound theoretical basis that is not contested	The size distribution of fish in the landings is accepted to reflect the processes of growth and mortality
Public awareness	- Does the indicator have high or low public awareness	Awareness and clarity in relation to what the indicator is measuring is important if there is to general acceptability of management responses to changes in the indicator	Catch per unit effort is generally accepted by fishermen as an indicator of how many fish there are on the fishing ground
Costs	- Measured using low costs - Complex and expensive to measure	The indicator must be measured systematically in the long term. Fisheries management is a long term process. There is little point in embarking on fixed term 'projects' which cannot be continued because of lack of resources.	It is usually feasible to record how the fishery is performing i.e. to measure landings and effort. The industry provides the data and the management authority can focus on ensuring the quality of the data is being maintained and well managed
Measurement	- Bias and variance measurable - Bias can be estimated negative/positive, low/ high - Precision can be estimated - Seasonal variation systematic or irregular - Spatial scale of variation	Ideally sources of bias should be identified and if possible estimated. At least intuitively it will be useful to know if the bias will make the indicator more or less precautionary.	There may be many sources of bias in the catch per unit effort data; changes in catchability may occur, the true relationship between stock biomass and CPUE may not be linear over all stock sizes. Discontinuities in the time series because of subtle changes in the way data are collected can introduced bias.
Historic data		If historic data exists for a given indicator it will be better to continue with this indicator if possible.	
Sensitivity	- monotonic response high slope - monotonic response low slope - monotonic within limits - unreliable - insensitive and independent of pressure	The sensitivity of the indicator to underlying changes in stock status should be sufficient and resolvable to be useful for management.	For instance if the stock biomass changed by 20% and the CPUE index remained flat then the index is insensitive (unresponsive). The sensitivity is also related to the precision of measurement i.e. finding differences across years will depend on how precisely the index is measured in each year. It is more likely that good precision will be achieved with higher volumes of data Size composition data in some fisheries such as crab and lobster can be very insensitive to changes in fishing effort (which itself is a proxy for fishing mortality). The reasons are unclear.

Responsiveness	- within 3 years decadal	How quickly will the indicator respond to changes in stock status? If there is a long lag between changes in stock and changes in indicator then the indicator will be less useful (unless the lag is known at the outset)	Changes in an LPUE indicator may reflect changes in the biomass of commercial sized fish but indicates nothing about recruitment.
Specificity	- low response to other factors - responds to other factors in known ways - unresponsive to other factors - responds unpredictably to many factors	Are there factors other than changes in biomass or changes in fishing effort that can affect the indicator? Ideally there would be low response to other factors	An LPUE indicator responds obviously to changes in fish discarding practice on board e.g. if vessels high grade for reasons other than the minimum size e.g. market requirements the LPUE indicator is then responding to the market and not to changes in stock biomass!

Harvest Control Rules

Overview

Harvest control rules are management actions linked to measures of fishery performance that intend to achieve fishery objectives. Harvest control rules encapsulate good management of the target stock, as they define practical objectives, measures of performance and appropriate management actions required to ensure fisheries meet their objectives.

Most fishery management can be couched in terms of harvest control rules, and in this sense, such rules are nothing new. However, these harvest control rules have tended to be vague, consisting of general idea that a committee of decision-makers will take action when, are reviewing various indicators, it feels such action is necessary. What MSC certification demands is that these rules are well defined. This means that rather relying on decision-makers making good decisions when the need arises, such decisions are pre-defined, usually in the form of a measurement-evaluation-response feedback loop.

Good MSC harvest control rules should have the following attributes:

- Testable: It should be possible to test harvest control rules with the best available science and covering possible states of nature (uncertainties), providing evidence that the management system should work.
- Transparent: The harvest control rule should clearly define objectives and how management will respond to changes in the fishery, accessible to all stakeholders.
- Auditable: Explicit reporting of indicators and decisions against those agreed in the harvest control rule allows stakeholders to see whether management is following its own agreed policies.
- Participatory: Identifying and agreeing the harvest control rule is the task of all stakeholders. The design of the harvest control rules should be an integrated decision between scientists, managers, regulators and the fishing industry. Scientists can help the process by providing information on “what if” scenarios through simulating using the decision rules.
- Timely: Harvest control rules consist of pre-agreed actions to be taken in response to changes in stock status. This may be particularly important where stocks status may change rapidly (e.g. bivalve and shrimp stocks).

Most harvest control rules that are consistent with MSC certification can be structured as IF THEN conditions. For example, IF the stock status indicator is below the target but above the limit reference point THEN a decision is taken to implement a pre-agreed temporary reduction in harvest.

The harvest control rules or strategy could be based around changes in catch levels, effort levels,

or allowing for a fixed spawning escapement and implemented using a range of harvest control tools such as reduction in the number of vessels, reduction in the amount of gear in the fishery, closing the fishery for a period of time to reduce overall annual fishing mortality.

Harvest control rules could become complex with nested conditions or ‘fuzzy logic’ conditions that incorporate the status of multiple indicators used to assess stock status and environmental impact, for instance. However, for reasons of transparency and to promote stakeholder involvement, the rule should be kept as simple as possible. It should be demonstrated that more complex rules have a better performance than simpler versions.

HCRs are constructed around reference points, which also determine stock status. For the current MSC methodology, two reference points need to be established; a limit reference point and a target reference point.

The target reference point needs to be agreed by stakeholders, with the constraint that the biomass should on average be at a level that allows the stock to be highly productive (provide Maximum Sustainable Yield). The target represents what the stakeholder wants from the resource in terms of catch rates and size composition over the long term.

The limit reference point will be related to the biology of the stock and specifically identified to protect recruitment. It is likely that the most accurate limit reference point that could be estimated would be 20% of unexploited spawning stock or 50% of the stock size at MSY. The HCR should seek to remain above the limit reference point at all times.

The reference points need to be established even if the science is lacking. Precaution can be used to set reasonable reference points based on the current understanding of the stock dynamics.

The harvest control rules (HCR) must be applied through a “HCR tool”. Broadly these are controls that are applied all the time to limit the level of harvest, and a particular control that should be responsive to the stock status, so that harvest can be reduced if necessary.

The type of control will need to be decided and may vary between fisheries. For quotas, whether they are shared or individual based, and whether they are transferable or not will also need to be considered. Controls are likely to be:

- Catch quota: The traditional control which works well if well enforced. The appropriate level of catch may be difficult to calculate and may require re-estimation each year.
- Effort quota: Effort quotas are particularly useful as they limit fishing mortality on the bycatch as well as the target stock (see Appendix A). However, catching efficiency will need to be limited or the effort quota adjusted as efficiency increases.
- Area access: Area use rights could be agreed for static gears such as traps. To an extent access to areas is already controlled through traditional activity, but not necessarily formalised. Formalising could probably be linked to effort quotas above, but it would also be possible to link area exploitation to a rule which would increase the area set-aside if the stock decreased in size. This approach has not been widely applied, but is used in traditional management systems in the Pacific Islands.
- Seasonal Access: It would be possible to establish seasonal closures for some fisheries. These would not be individually based but apply to the whole fishery. Seasonal closures could be variable length to meet the requirements of a harvest control rule and would in effect work in a similar fashion to the effort quota.

As well as a main harvest control, additional fixed controls can be implemented to protect spawning or nursery areas, or spawning times or other part of the stock which is seen as vulnerable. Fixed closed seasons and areas are often used in addition to other controls. Generally, the more controls that are successfully applied, the lower the risk to the fish stock. Some fixed controls can be highly effective at protecting the stock and yet may have a minimum impact on fishing activity.

Each fishery needs a management authority made up of stakeholders or stakeholder representatives. The management authority should be responsible for making decisions and administering the system, including allocating any catch or effort quota among the relevant stakeholders, monitoring the uptake of the quota, and ensuring that fishing is not in excess of the quota.

The HCR will need to be subject to review to ensure that the correct decision is made and to apply any extenuating circumstances in a measured fashion. When HCRs are first implemented, it is likely they will need to be adjusted. An alternative harvest level could be set temporarily under special circumstances similarly to applying a temporary subsidy, although there should be a clear cost associated with this. A better approach is a to agree changes to the HCR based on experience of its actual application after a trial period.

We focus on implementing harvest control rules based on simple empirical indicators of stock status that determine when an additional management intervention may be required. Although other controls, for most fisheries these are already in place, and it is variable control used to implement the response part of the HCR that is lacking.

Reference Points

While HCRs can be constructed on simple empirical indicators, setting reference points which decide the maximum harvest and exactly when the harvest will be reduced is more difficult.

Target and limit reference points are a requirement for MSC certification, so it makes sense to define a harvest control rule in these terms. An indicator's target reference point defines the approximate value of the indicator when fishing is normal and the stock is at full reproductive capacity. The limit reference point defines when the risk to the reproductive capacity of the stock becomes unacceptable, and the harvest should be reduced to the lowest level possible to ensure that the stock recovers back to its target. Between the limit and target points, at least one trigger point will be required that defines the point where management intervention is required to prevent the stock approaching the limit reference point.

The target exploitation level should be set no higher than levels which achieve the long term maximum yield (see Box 2). The modern meaning of Maximum Sustainable Yield (MSY) takes into account risk, and may require stock biomass to be maintained at levels well above a point estimate of MSY obtained from a deterministic stock assessment model.

Catch rate target reference points may be justifiable if it is reasonable to assume or it can be shown that CPUE responds to stock size and some evidence exists to propose and justify reference points. Because CPUE can be related to economic performance, it should be possible to get agreement with stakeholders over HCR reference points, although showing that these are precautionary enough to meet conservation objectives may be more difficult.

Most fish stocks show a poor relationship between stock size and recruitment. Recruitment is highly variable, so any relationship apart from when the spawning stock is heavily depleted is difficult or impossible to detect for most stocks. Therefore, a default safe limit reference point may be used unless an alternative can be justified. For non-low trophic species, this is 40% of the unexploited spawning stock.

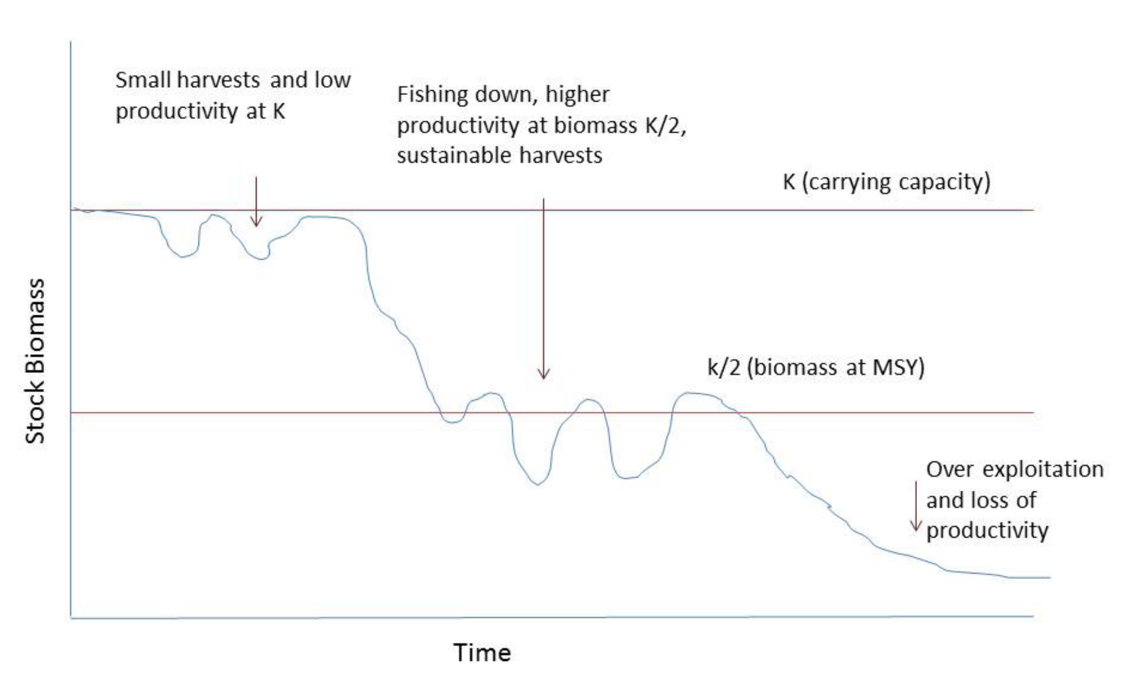
For short-lived species, such as bivalves and shrimp, there is a greater dependence on single recruitments since the age structure is very truncated. For these species, management action may still be required to protect stocks when they fall to low levels due to periods of natural low recruitment or high natural mortality. However, for cockles, mussels and scallops, size at maturity usually occurs well below the commercial size, which tends to protect the spawning potential even at high harvest levels (Box. 3). These species also have high fecundity and they generally can recover rapidly from low population levels, making them robust to fishing.

As well as stock productivity, reference points may need to take other issues into account:

- Ecological role of the stock: Bivalves may be an important food source for a variety of shore

birds, and therefore their needs may need to be taken into account in setting targets.

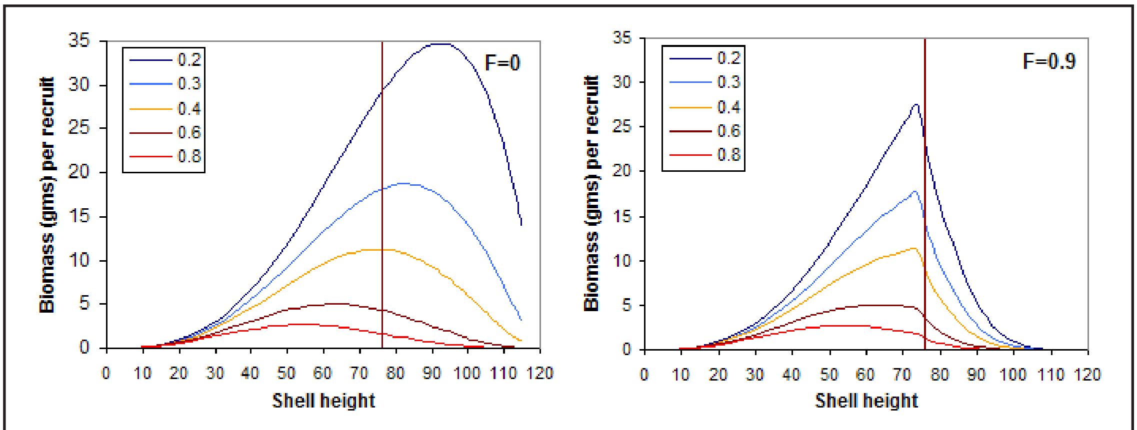
- Density: For sedentary species (e.g. bivalves) fertilisation success depends heavily on proximity of male and female spawners. Maintaining a minimum density therefore also needs to be considered in estimation of the limit reference point.
- Habitat: As density decreases , fishing may become more intense causing damage to the habitat and long term reductions in productivity. This should be taken into account if necessary in setting targets and limits.



Box 2:

Concept of unexploited stock size (carrying capacity) and MSY in relation to harvests over time.

Where carrying capacity (K) can be observed or estimated, it might be assumed that MSY occurs at half of this value potentially, provides a target reference point for management.



Box 3:

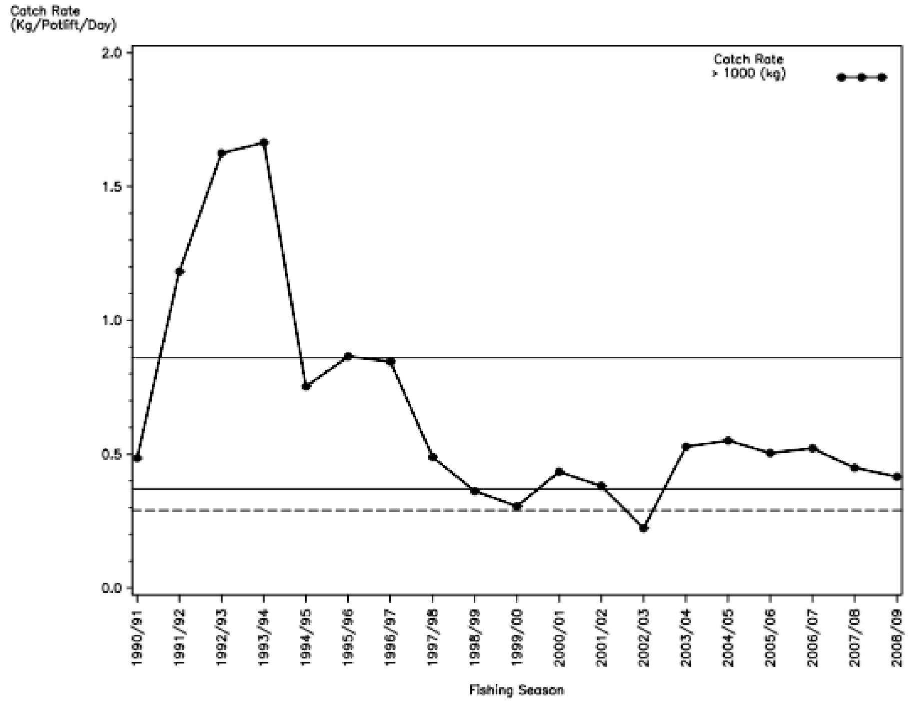
Potential yield per recruit or total yield if raised to numbers of oysters at different sizes under different conditions of natural mortality with no fishing (F=0) and high fishing effort (F=0.9) in an oyster fishery in relation to a MLS of 76mm.

Management and optimising of yield from bivalve beds is a balance between natural mortality and growth rates; at low natural mortality better yield can be obtained by delaying harvest to larger sizes and vice versa.

Box 4:

Giant crab (Pseudocarcinus gigas) by Australia, Victoria (top) and South Australian commercial blue crab (bottom) have used historical information on catch and effort to propose and have accepted reference points based on past biological and economic performance.

Within the context of MSC certification, reference points will need to be justified on the basis of stock productivity, not only on past fishery performance.

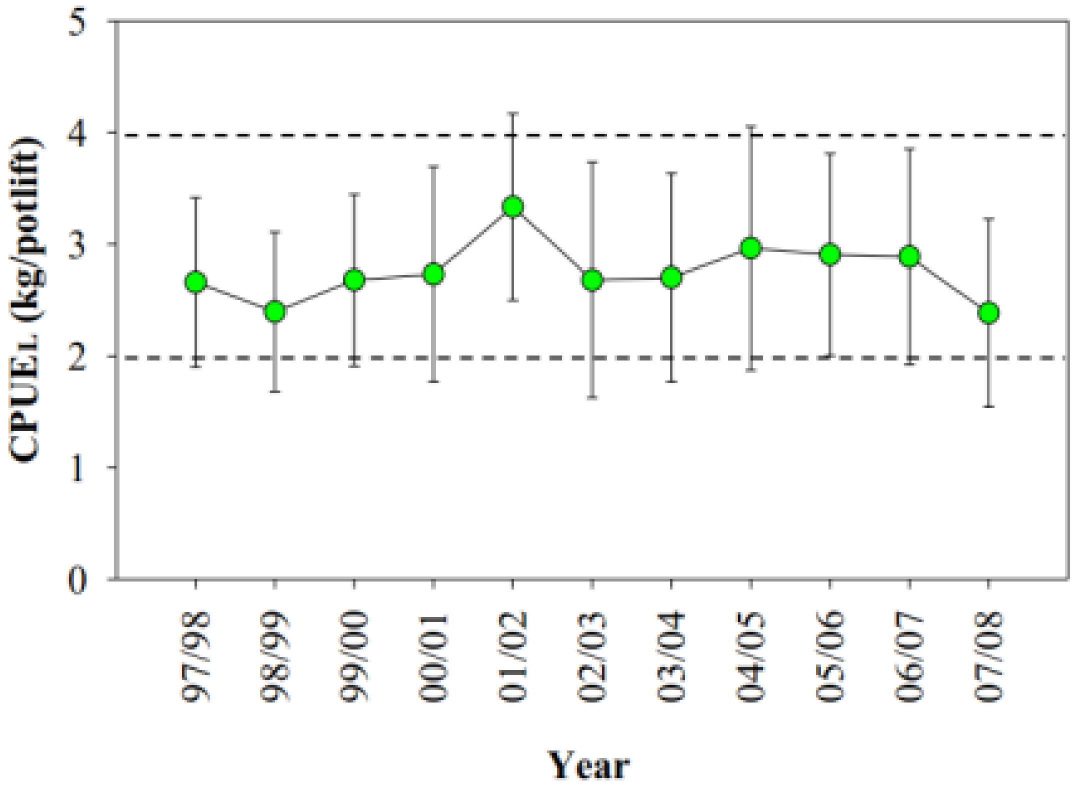


Note – Reference points in the Victorian Giant Crab Fishery Management Plan

The target reference point is 50% of the peak CPUE recorded in the fishery in 1993–94

The limit reference point (CPUE of 0.36kg potlift/day) was determined by averaging catch rates for the period between 1998/99 to 2000/01. This is a trigger point for a TAC review.

The dashed horizontal line is the CPUE trigger point (80% of the limit reference point) for a mandatory TAC reduction.



Management Controls

There are a limited number of types of harvest control tools that have been used successfully, although all have strengths and weaknesses (Table 11). Input controls limit effort such as vessel-based limited entry, trap and days-at-sea limits and closed seasons. Output controls limit catches, through a total allowable catch (TAC) usually applied to landings. Finally, technical measures are controls placed on the gear, such as mesh size, minimum landing size, escapement hatches and so on.

As well as the harvest control, additional fixed controls can be implemented to protect spawning or nursery areas, or spawning times as required. Fixed closed seasons and areas are often used in addition to other controls. Generally, the more controls that are successfully applied, the lower the risk to the fish stock. Some fixed controls can be highly effective at protecting the stock and yet may have a minimum impact on fishing activity.

Closed seasons serve three purposes: to reduce or limit fishing effort, to protect spawners or juveniles from exploitation or to introduce contrast in monitoring data series. The main problem with closed seasons is they enforce a period when fishers are unable to earn money.

Closed seasons are sometimes useful for enforcing current practice. Many inshore fisheries are seasonal in nature, so enforcing a closed season when fishing on a particularly stock does not much occur anyway would seem to serve no purpose. However setting a closure sets a precedent that could be extended into the fishing season (as for cuttlefish for example) and puts in place a control that might limit expansion in the fishery to unsustainable levels, if for example, prices for the product increased.

Closed areas can be used to protect a section of the population and thereby prevent overfishing. They also may provide an indication of what an unexploited stock might be like, which is important for developing good reference points. The disadvantage of closed areas is that they require understanding of the spatial distribution and movement of the population. Given the difficulties of working with one dimension, time, the addition of 2 or 3 more dimensions in an analysis is usually beyond the capacity of stock assessment methodologies. Closed areas are therefore proposed on limited information and therefore their performance will be uncertain. Nevertheless, they are an important tool in applying the precautionary approach, particularly for limiting impact on habitat as well as potentially providing information for decision-making.

Tagging can be used to protect a proportion for the stock. Voluntary V-notch programmes are used to identify spawning females in lobster fisheries that have been returned to the sea after capture, for example. Releasing females should reduce effective fishing mortality on the spawning stock at the obvious cost of having to return valuable catch to the sea. Tagging may also be used to provide important information on growth, movement and mortality.

The effectiveness of any tagging programme designed to protect the stock needs to be assessed. This also requires recording and reporting tag returns and recaptures.

Table 4:

Some strengths and weaknesses of different harvest control tools that will need to be considered

Input control	
Strengths	**Weaknesses**
May be more suitable than output control in mixed fisheries or where discard mortality is high	Limited entry is a necessary precursor to limiting individual vessel effort
May be more relevant to the twin objectives of stock conservation and environmental protection	Increase efficiency in gear can reduce effectiveness
Input control can also improve fishery economic performance	Standard units of effort should be identifiable
	Spatial control may displace effort to other areas
	May be difficult to implement and monitor
Output control	
Directly limits fishing mortality	Estimating an appropriate TAC may be difficult for some species.
Controlling landings may be easier than controlling effort at sea	Imbalance between fleet capacity and TAC can easily arise unless capacity is also limited
	Not effective in limiting fishing mortality when discard mortality is high
	The link between the TAC control and subsequent stock status may be weak
Technical measures	
Easy to implement and control	All technical measures are 'designed' to reduce fishing efficiency and thereby reduce profitability
May be effective at controlling fishing mortality without input or output controls	In the absence of input or output control technical measures need to be increased to limit fishing mortality as landings or effort increase.
	In some species appropriate measures may be difficult to design because of size at maturity relative to the market size.

Purpose of Stock Assessment

For empirical indicators, such as mean CPUE, the main task of stock assessment will provide be estimate appropriate reference points and, through projections, provide a simple test of the harvest control rule.

The assessment method will be largely decided upon by the available data, and indicators required. Methods do exist which are less sophisticated that age-based assessments, but still make use of limited data. These can be applied in most cases with a variety of additional methods used to fill in data gaps.

With careful choice of indicators which are relatively inexpensive to calculate, stock assessments need only be conducted infrequently. A stock assessment is technically difficult to conduct and requires considerable technical expertise, which is in short supply. Stock assessments may be required to initiate the management process and perhaps could be conducted every 3-5 years as part the monitoring process.

We would recommend that stock assessment applies Bayesian fitting methods so that all sources of information can be used and uncertainty can be taken into account in providing the best scientific advice. A stock assessment is unlikely to have sufficient data from the fishery alone to estimate reference points or a robust harvest control rule. It is therefore likely that additional information will be required from some supporting research carried out in the short and medium term for each fishery. The different sources of information can be most easily incorporated through Bayesian statistics, which offers a very flexible framework, particularly where data are limited.

Developing Harvest Control Rules

Main Tasks

The target reference point needs to be agreed by stakeholders, with the constraint that the

biomass should be greater than or equal to the MSY level. The target represents what the stakeholder wants from the resource in terms of catch rates and size composition over the long term. Agreement might best be reached through a workshop with technical / scientific support.

The limit reference point will be related to the biology of the stock and specifically identified to protect recruitment. It is likely that the most accurate limit reference point that could be estimated would be 20% of unexploited spawning stock or 50% of the stock size at MSY.

The reference points and harvest control rule need to be established even if the science is lacking. It is unlikely that all information necessary to provide full scientific advice would be available when initialising the management process. Nevertheless, innovative methods and precautionary approach can still be used to arrive at decisions over appropriate reference points and controls. In those cases where evidence is lacking and subjective judgement needs to be applied in setting the HCR, external independent review is useful test and evidence that the HCR is reasonable and precautionary.

The indicators, reference points and harvest control rule would best be established through a stakeholder workshop facilitated by management and technical support. The task of the workshop would be:

- For stakeholders to understand the current scientific information, including the stock assessment, and any relevant scientific research.
- For stakeholders to supply their information for inclusion with the technical data,
- To identify critical issues where there is disagreement among stakeholders, if any, and identify tasks to resolve those issues. Science has an important role in resolving such disagreements.
- To agree the management controls, indicators, reference points and harvest control rule for an initial management plan. To facilitate this, simulation tests of various management options should be conducted and presented during the workshop.
- To agree a research plan to close out issues and improve the management of the fishery.
- To identify management activities and controls which will be needed to implement good management practice.

Even with a good data collection system, the information content of the data on parameters used in the harvest control rule may still be insufficient. Special research projects and adaptive management have a role in providing improved knowledge in these situations.

Supporting Research

A literature review to identify information and, where necessary, develop “priors” including estimated uncertainty, will be required. Various stock assessment methods require independent information on growth, length-weight, reproductive rate, fecundity, natural mortality and so on. These often cannot be estimated from fishery data alone, but require specific research. Even if research has not been conducted on the stock or species concerned, information may be obtained from similar stocks, species and/or fisheries.

A rapid short term data collection programme should be conducted to allow morphometric conversions for the stock, mainly conversions from length to weight and the reverse, if these are not already available. The data are simple to collect and the analyses simple to undertake, and results are very useful for a variety of purposes in stock assessment as well as validation of various reported statistics.

It may be necessary to conduct specific studies on population dynamics such on growth and recruitment. This research will reduce uncertainty. Research specific to the stock may be considered desirable even if relevant research on the species exists in the scientific literature. Growth rates will vary with average temperature, and local conditions may be considered sufficiently different to justify a specific scientific programme. The costs involved in this sort of research would form an important part of the decision over whether such research would be

desirable.

Simulation Testing

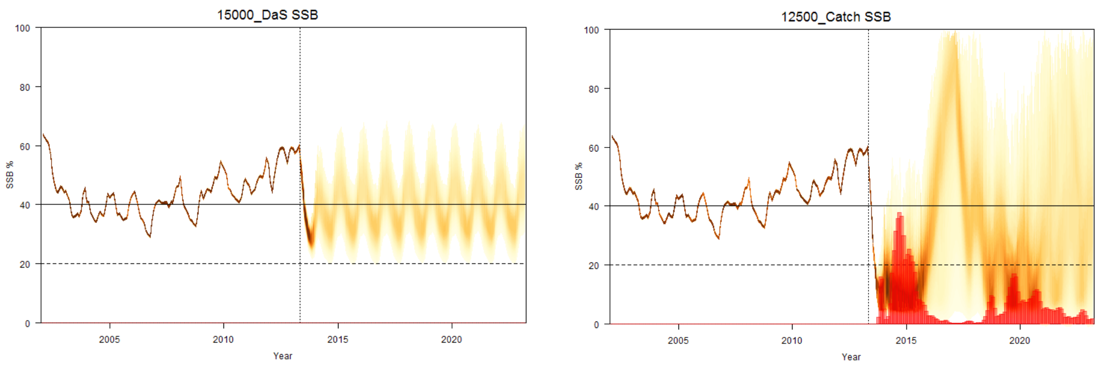
Harvest control rules can be tested through simulation before they are put into practice. This can be used to design the system in such a way that management errors are minimised. Simulations can be used to represent a very wide range of possible scenarios and therefore improve the robustness of management tools. However they are limited in that not all eventualities can be tested and the scenarios are tested on a model which is a simplification of the real world.

Simulation testing can be carried out rapidly, as long as the proposed procedures are simple, and should form part of the process for deciding upon the harvest control rule. Simulations can be conducted during the management authority meetings to give immediate feedback on proposals and provide advice on various options among which the participants must choose (Box 5).

Simulations are particularly important in considering risks not only of sampling and structural error, but also of violating key assumptions. This should help in designing robust harvest control rules and monitoring systems to ensure management is sustainable.

Box 5:

Risk simulation of spawning stock biomass (% of unexploited) with two harvest control rules presented to stakeholders to aid design of a harvest control rule.



The stock is projected applying the HCR after the vertical dotted line. Colour density represents probability, so the dispersed lighter colours indicate greater uncertainty. The horizontal lines are the target (solid) and limit (dotted) reference points. The top simulation is based on applying an effort control (15000 days at sea) to a short-lived shrimp species, which appears to meet management objectives. The bottom simulation is based on the same indicator and reference points, but applies an annual catch quota (12500t). The red histograms at the base of the graph represent stock collapse (SSB < 5% unexploited), and was used to illustrate that annual catch quotas for this species may not achieve management objectives unless the catch limit is set very low.

Parameter Estimation

Stock assessment works by linking detectable declines in abundance (depletion) to catch levels. Broadly, within a time series, catches need to vary and be negatively correlated with measures of abundance, after allowing for other biological processes of recruitment, growth and natural mortality. Where such catches have not varied or do not correlate with abundance, the time series will have insufficient contrast to estimate parameters necessary to define reference points. Very often, data collection only starts when the management authority becomes concerned that overfishing might be occurring and the fishery has been fishing for many years, and therefore may lack this contrast.

If there is sufficient contrast in a standard time series, then standard stock assessments can be used to estimate reference points. If such contrast does not exist, it will be necessary to be more creative in finding periods when catch and abundance change significantly.

The management system may be used not only to protect the stock but also create contrast required for estimation. Closed seasons may enhance seasonal change. Closed areas provide spatial contrast, and if big enough and representative, may be used to indicate stock density with

no fishing (B_0 or K), which is an important parameter for reference point estimation.

Artificial depletions may also be created by fishing experiments. Fishing experiments can be used to produce data on the behaviour of a stock when subjected to intensive fishing. They require a relatively isolated but representative portion of the stock, which has been left unfished for a period allowing the population to increase, then a short period of intense fishing followed by another period of recovery. Importantly, by involving fishers in the experiment and purposefully depleting an area, the process demonstrates that fishers can directly affect the status of their local target stocks and reaffirms the importance of developing a management process. The method however is not suitable for highly migratory species, such as many pelagic fish or where no isolated sub-population can be found.

Fishers would be fully involved in designing and conducting the experiment. They should want to participate in an experiment because it seeks to provide information which will benefit the fishery and their knowledge.

Fishing experiments should provide detailed information on the target and bycatch stock abundance, size composition and sex composition. Detailed effort information (fishing times and characteristics of the gear and boat) could be useful in determining how effort can be recorded routinely. If possible, indices of stock size should be obtained before, during and after the experiment. Alternative indices could include visual census, the CPUE from some standardised gear or other method to measure local density. Any method can be used as long as it can be assumed that the index is proportional to the size of the fishable stock.

It is necessary to raise the experiment area to the total fishing area to obtain correct estimates for the relevant parameters. The simplest way to do this, which is recommended as an initial technique, is simply to raise the total catch in proportion to the experiment : total area ratio. With habitat map data, more sophisticated approaches might be used. In any event, bearing in mind that there will be some immigration and emigration unaccounted for and that the experiment only provides a snapshot of the stock at best, it is likely that the experiment data will allow uncertainty to be more narrowly bracketed rather than provide accurate parameter estimates.

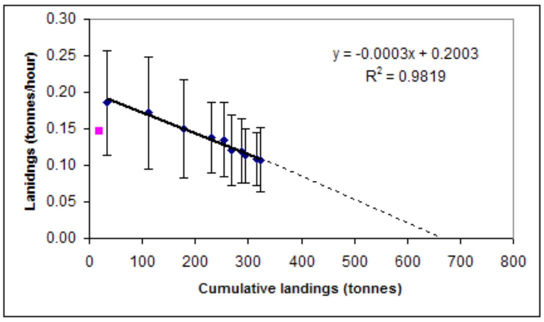
Tagging experiments can provide information on growth, movement and mortality, making them potentially very useful. Fishers can carry out their own tagging experiments: recording, tagging and then releasing individual animals. An advantage of a fisher-run programme is that recaptures are very likely to be reported. The disadvantage of tagging is the cost of this sort of programme.

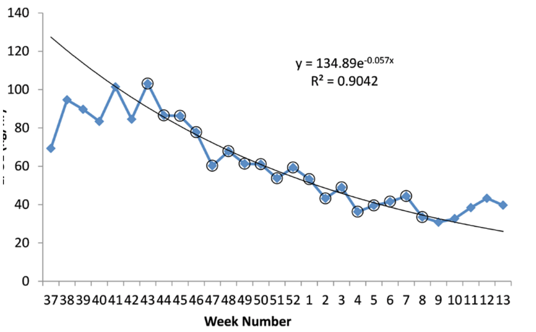
Marking animals with an individual number is preferable. This provides more information on growth and mortality than techniques like V-notch that do not identify individuals. Nevertheless, the practicalities and costs limit what might be done, and non-identifying marking is still informative.

Box 6:

Example of catch rate decline in a brown shrimp fishery within a year due to fishing and natural mortality.

The first points in the series are excluded as the stock is not fully recruited. The last points are excluded there is a second seasonal recruitment.





Biomass and exploitation rate can be estimated within seasons for many species where there is a strong seasonal recruitment or closed season. Where these fisheries which are intensively fished at the beginning of the season, catch rates decline as cumulative catch increases within a season. This can be used to estimate the pre-fishery biomass, escapement as well as link effort to fishing mortality. A within-season HCR could, for example, close the fishery once CPUE had declined to a predefined level and open again when the next recruitment is expected.

Top: Example of catch rate depletion during a cockle fishery as total outtake increases. Extrapolation to zero catch rates provides a pre-fishery estimate of biomass of cockles of 667 tonnes. The first point in the series is excluded as fishermen fine tune gear settings.

Example Generic Rule

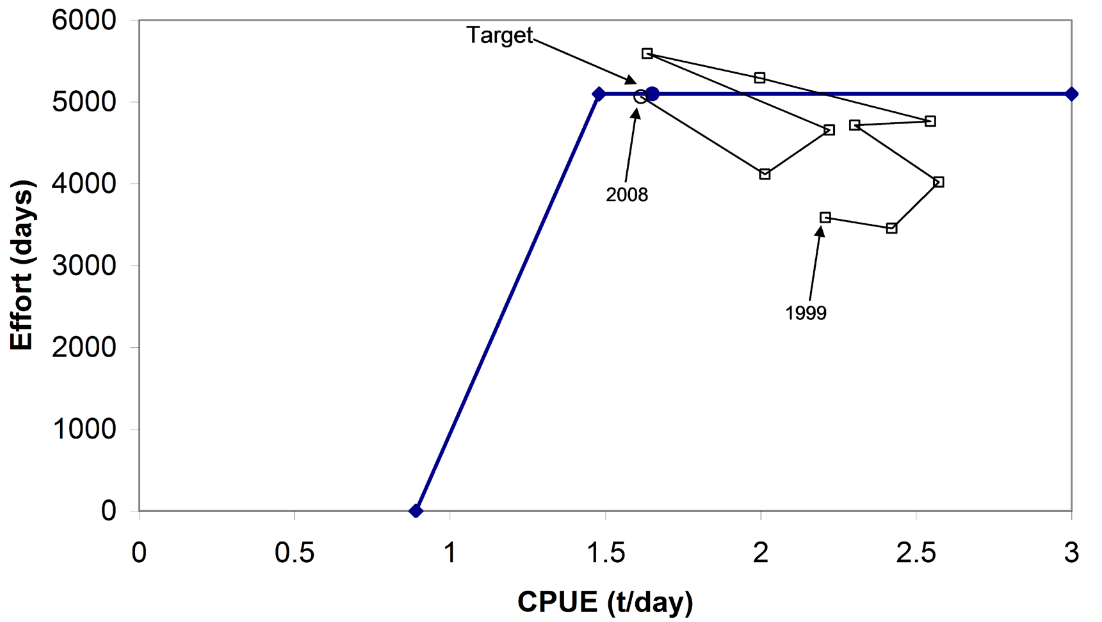
A catch rate indicator and fishing control can probably form the basis for a good harvest control rule in many small scale fisheries (Box 7). In this context, the fishery management objective is to maintain high catch rates, which translates to maintaining livelihood earnings for fishers. Under a wide number of assumptions, this can be achieved by capping the overall fishing effort and introducing special measures when catch rates fall below some sustainable level (trigger reference point). Fishing effort is also a particularly good control as it implicitly allows for adjustment in catch as abundance changes, if CPUE is a good abundance index.

If available, a stock assessment can be used to estimate reference points and harvest control rule based on these native indicators assuming that they are proxies for biomass and fishing mortality.

The key assumptions are:

- That catchability remains constant if using fishing effort or selectivity remains constant if using size as the indicator. If catchability or selectivity change, this will need to be estimated and additional data and research may be required.
- That sampling and other errors remain small compared to changes in indicators related to abundance or fishing mortality. This can be verified as data are accumulated over time.

Performance of the indicator can be improved by smoothing it over time. From a statistical point of view, dynamic models used in stock assessment are sophisticated smoothers through various data sources, so applying a smoother to an abundance index, for example, is a similar process. It is not known which smoothers might the best methods to use, and several might tested through simulation. However, it is likely that there will be little difference between different methods, and therefore in the absence of evidence for alternatives, the simplest (e.g. moving average) might be used. The degree of smoothing required will depend upon the level of noise in the indicator. A very noisy indicator (i.e. high observation error) will require high level of smoothing, but then will react more slowly to changes in the stock.



Box 7:

Generic harvest control rule implementing an effort (total days at sea) limit based on catch rate (t catch / day).

The reference points were chosen considering the MSY estimate, risks and economic performance of the fishery. The most important consideration for the operation of the fishery was the maximum days-at-sea and the trigger reference point.

The illustrated rule works as follows:

- The target catch rate shall be set at 1.65 tonnes per day-at-sea and the limit catch rate shall be set at 0.89 tonnes per day-at-sea.
- A trigger catch rate shall is set at 1.48 tonnes per day-at-sea.
- The total allowable effort will be 5100 days-at-sea when the current catch rate is at or above the trigger catch rate.
- The total allowable effort will decline linearly when the current catch rate is below the trigger catch rate according to the calculation: TAE = (Current Catch Rate – Limit Catch Rate) * 8625
- The fishery will be closed if the current catch rate is at or below the limit catch rate.
- The current catch rate for each year shall be calculated as the average between the previous year's current catch rate and catch rate of the current year. The catch rate is calculated as the total landings of seabob divided by the total number of days-at-sea for the fleet.

Administration and Monitoring Performance

Establishing Feedback and Control

Responsibilities need to be allocated among stakeholders. Ideally, a single group would not be responsible for the entire process, but responsibilities would be split into at least two areas so each group might oversee the other. However, for small scale fisheries, it may not be appropriate to have more than a single meeting where the two independent groups, managers/scientists and producers for example, might come together. The responsibilities and tasks are:

1. Converting data into information. This is primarily estimating the appropriate indicators and reviewing the data and calculations to ensure that they are correct. This task can be conducted by a designated technical staff who should also be a member of the management authority.
2. Deciding upon the level of control, abiding by policy decisions. If there are no extenuating circumstances, this should be a simple case of applying the harvest control rule. This can be carried out either by a group or, if the harvest control rule is to be applied, through review then dissemination of the result. If there is a meeting, the results and recommended control should be reported and enough information provided so that the meeting can ensure the calculations and results are correct. Unless there is clear evidence to set an alternative control, the agreed

harvest control rule should be applied. If the harvest control rule is broken, it implies a review of the policy and rule is required.

3. Enforcing the decision. This should consist of, at the very least, dissemination of the decision so that all stakeholders are made aware of their responsibilities for the coming season. It may also involve a third party to ensure the quotas are adhered to. As long as a general agreement has been reached, most stakeholders should keep to their quota.

Regular meetings of decision-makers are required commensurate with the likely rate of change of the stock. In most cases, meetings would be annual, but where a transparent rule is being applied, meetings may only be rarely required to review the performance of the controls and other matters pertaining to the management of the fishery. Furthermore, the management of several fisheries might be reviewed at the same meeting, making the system relatively efficient.

The management authority will need to initiate the process by making the following decisions:

- The harvest control rule which determines the overall quota;
- An agreed division of the quota among the stakeholders;
- Various other static management controls to limit fishing mortality and decrease risk to the target and bycatch fish populations.
- A research plan to inform the management process.

Evaluating Management Performance

It is important that the management performance undergoes periodic review. This need not necessarily be frequent (every 3 to 5 years, for example), but ensures management performance is maintained at a high level, that the management authority is undertaking its basic tasks correctly. To aid the review, the vision, goals, objectives, outputs and tasks of the management authority, together with the terms of reference and results of meetings need to be documented. The review can also be used to identify possible improvements.

A scientific “working group” could be established to oversee any research activities, review the indicator calculations, the reference points and harvest control rule. They can also develop and mark the progress on the research plan. Working groups made up primarily of scientists are used to provide scientific advice to managers in most fisheries management systems. A small group of local scientists could perhaps be brought together periodically to cover all stocks under this management system tasked with scientific review of the relevant aspects of the management strategy and to provide general technology support to the management process.

Fishery Management Plan

It is useful to compile summary information on a fishery and its management into a single document, a fishery management plan. Fishery management plans can turn into unwieldy large documents full of detailed information about a fishery and biology of the target species. While this information can be useful, the primary purpose of a plan is to describe management practice as it is and therefore will need to be updated frequently. Justification of current practices can be included in summary form, but full explanations should probably be referenced as separate documents and reports. If the plan is kept short, it will be much easier to keep the plan up-to-date and ensure stakeholders are aware of its contents.

The plan should be updated annually, and provide summary information on:

- Current stock status and summary information on the performance of the fishery (e.g. total catch, effort, number of fishers, short summary of any relevant stock assessment or research).
- Summary of important management issues as raised by a management or stakeholder group
- Management procedures (who meets when and where)
- Roles and responsibilities and relevant contact information of representatives

- Harvest control rule definition
- Data collection protocol
- Research activities

MSC Harvest Strategy and Other Management Advisory Frameworks

The MSC integrated harvest strategy is consistent with the objectives expressed in the ICES approach to fisheries advice, the Marine Strategy Framework Directive (MSFD) and as expressed in several international agreements and polices such as the World Summit on Sustainable Development (WSSD) (Johannesburg Declaration of 2002). Indirectly, through the combination of the harvest strategy and Principle 2 on ecosystem effects, it is also likely that implementation of the MSC standard would mean that if such fisheries were in Natura 2000 sites that they would have an improved chance of 'passing' Article 6 (Habitats Directive) assessments.

The concept lying behind the MSC standard, MSFD and WSSD is maximum sustainable yield (MSY). The objective is for high long term yields from productive fish stocks in a healthy marine ecosystem. EC policy (EC 2006) calls on Member States to transit towards MSY by 2015 and the MSFD requires that good environmental status (GES), of which MSY is a component, by 2020.

The MSY approach to management is essentially about:

- Productivity (of stocks)
- Stability (of stocks and fisheries) and
- Reducing risk of a long term decline in productivity

The technical basis for the MSY approach and its implementation is well described in ICES (2013). Implementation of the MSY approach is about managing fishing mortality and not about managing stocks (biomass); stock biomass cannot be managed as such but fishing mortality can be managed such that on average the expectation that stock productivity and biomass will be high.

The ICES framework recognises that data and stock assessment varies across stocks; stocks are categorised according to the type of data that are available, the assessments that can be undertaken and the certainty of the advice that can be given.

In the case of shellfish (bivalves and crustaceans), available data and assessments may be insufficient to provide definitive advice in relation to MSY. However, it is important to recognise that the MSY concept is principally expressing a management objective rather than dictating that a single point estimate of stock status (of what MSY is) be provided. Therefore, even when analytical stock assessments are not available the MSC harvest Strategy can be implemented by adopting, for instance, the ICES advisory framework to move towards the objective of achieving highly productive stock and getting 'pretty good yield' from them.

The ICES framework is instructive with respect to **possible** approaches to implementing the MSY objective (Table 12). However, the framework is based solely on output (catch, TAC) control rather than input (effort) control or technical measures and many different assessment methods, as described later, could be used to provide advice in relation to MSY.

It is very important to acknowledge that even at the extreme of 'poor data availability' even some management structure can be put in place. The ICES Framework (Table 13) attempts to put some structure on the reporting of these situations. Importantly this makes the point that

- it is better to have some management rather than none and
- it is important to explicitly acknowledge the state of play with respect to the quality of advice that can be given

In really data poor situations it is important that stakeholders and managers begin to ask the right questions rather than seeking definitive advice from science that is simply not available in the short to medium term. Such questions might include:

- What is the collective impression (science and industry) of the status of the stock or exploitation rate
- Can agreement be obtained on a harvest control rule that is not evidence based
- Can systems be put in place to improve data provision
- Can an explicit management objective be agreed for the stock

Table 12:

ICES advisory framework for stocks for which there are different levels of data and assessment

Approaches to stock assessment, other than listed, are possible. The level of precaution increases from stock category 1-6 as the uncertainty in the advice increases. Although the harvest rules are in all cases based on controlling catch, effort adjustment, that may be expected to reduce catch, could also be used.

ICES stock cat.	Description	Assessments	Strategy	Implementation (Harvest rule)	Explanation	Example shellfish stocks to which this could be applied
1a	Long lived species	Quantitative analytical	Fmsy (2020)	Catch advice for Fmsy	Advise on catch levels corresponding to a fishing mortality that will in the long term generally maintain stock biomass at MSY	Scallop (e.g. Marine Science Scotland assessments)
1b	Short lived species	Quantitative analytical	MSY Bescapement	Initial TAC adjusted during season	A spawning escapement harvest strategy is implemented by setting an initial low TAC and adjusting it based on new data obtained during the fishing season and setting the final TAC to protect a minimum spawning biomass from fishing mortality	Shrimp (Crangon), cockle, mussel
2	Species with no population estimates	Qualitative analytical	F0.1 or other reference point more precautionary than Fmsy. Length based reference points Lopt etc.	Catch advice for chosen reference point that is likely to be sustainable	F reference points based on per recruit assessments using assumptions about natural mortality. Sensitive to spatial variability in growth Length based reference points can be developed for stocks where size distribution data are available in relation to size at first capture and size at maturity to indicate the likely stock status when biomass and fishing mortality are unknown (ACOM 2012)	Lobster, crab, scallop, whelk
3	Species with catch rate indices (survey, commercial)	Trends	Catch causes reduction in biomass as reflected in trends	Pro-rata change in catch advice in parallel with change in trends	If catch exceeds the biological production the stock biomass will decline. If the trend indicator is unbiased the decline should be reflected in it. The advice will be to adjust catch according to trends in CPUE index	Lobster, crab, scallop, whelk

4	Species with catch data only	DCAC (depleted corrected average catch)		Average catch is adjusted according to indications of changes in biomass	Average catch for a period of time is adjusted according to the degree to which the biomass might have declined during that time	Species where rate of natural mortality is low (<0.2) such as lobster, and whelk crab
5	Species with landings data only	PSA risk analysis	Risk management	Estimate productivity and susceptibility and adjust catch to reduce risk	Stocks that are fully vulnerable to the fishery (no spatial, temporal or size reserve) and where their biology indicates low productivity (k selected) could be more at risk than others.	Any species. May be useful for bivalves where distribution of fishing is changing year on year.

Table 13:

Structured reporting for stocks where only qualitative information is available

Modified from ICES 2013

Qualitative evaluation	Explanation	Text	Advice
Exploitation rate	**If there is qualitative information on the exploitation of the stock in relation to any possible reference points**		
	If F is very high then F>possible reference points	Provide description or rationale	Reduce catch or effort
	If F is very low then F<possible reference points	Provide description or rationale	Status quo pending improved assessment
Biomass	**If there is qualitative information on the stock biomass in relation to any possible reference points**		
	If SSB is very low then SSB< possible reference points	Provide description or rationale	Reduce catch or effort
	If SSB is very high then SSB>possible reference points	Provide description or rationale	Status quo pending improved assessment
Trends only	If indicator trend increases		Status quo pending improved assessment
	If indicator trend decreases		Reduce catch or effort
	If indicator stable		Status quo

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